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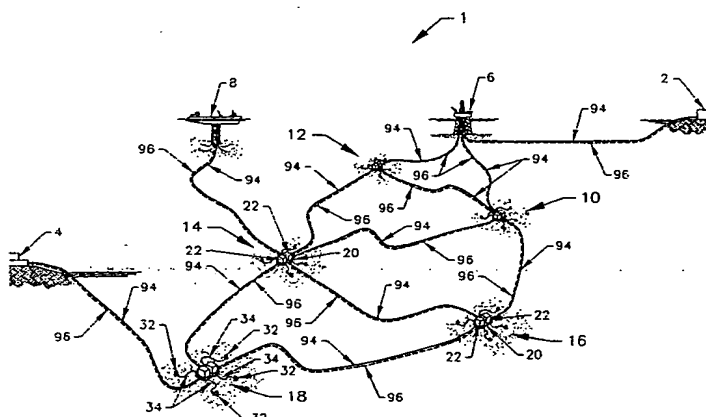
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**Declarations under Rule 4.17:**

— as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN,

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(54) Title: SUBSEA HYDROCARBON PRODUCTION SYSTEM



(57) Abstract: A system (1) for extracting subsea hydrocarbon fluid has five discrete subsea developments (10, 12, 14, 16, 18) for hydrocarbon extraction linked to four hydrocarbon receiving facilities (2, 4, 6, 8) by a pipeline network (94). Each subsea development (10, 12, 14, 16, 18) has a manifold to which pipelines of the network (94) are connected, and a pair of retrievable modules (22) docked on the manifold. Each module has a control pod which is able to control flows of fluids between the subsea developments and between the subsea developments and the receiving facilities, and each control pod is connected to monitoring devices for monitoring parameters pertaining to the subsea developments. Parameters are monitored at a first one of the subsea developments and a requirement for a first fluid type is identified and parameters at another second one of the subsea developments are monitored and a surplus of the first fluid type is identified. The relevant control pods are then operated to enable a quantity of the first fluid to be conveyed from the second to the first subsea development via the pipeline network (94).

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SUBSEA HYDROCARBON PRODUCTION SYSTEM

The present invention relates to a system and method for extracting hydrocarbons from subsea reservoirs and more particularly to a system including plural geographically separate fields.

Where plural separate fields are to be exploited, a host facility is normally provided with fluid pipelines, control/power lines etc. radiating out therefrom to extraction facilities at different locations. Each extraction facility may include a central unit connected to receive fluid from a plurality of wells. This fluid may include a mixture of fluids including hydrocarbon liquid, hydrocarbon gas and water, the volumetric ratios of which to each other will vary considerably from field to field and throughout the life of a particular field. In certain situations the extraction facilities are connected to each other in series in a so-called daisy chain arrangement, the series connected extraction facilities being connected to a host facility. In general, the majority of the fluid produced by the fields is all conveyed to the host facility and if any fluid needs to be provided at an extraction facility (e.g. water for pressure boosting injection into a subsea reservoir) it is pumped from the host facility to the particular extraction facility. The capital cost associated with installing the pipelines for conveying the fluids is very high and any cost saving resulting from the pipelines being designed for a lower volumetric throughput is extremely desirable. It is also desirable to minimise the amount of water which is returned to the host facility because water so returned needs extensive processing prior to disposal overboard and can accordingly incur a tariff. A further drawback with existing series connected or radially connected extraction facilities is that if a pipeline needs to be taken out of service for any reason, then the flow of fluid being conveyed by the pipeline is interrupted which may effectively result in the shutting in of one or more fields. In addition to reducing production output, such shutting in may also make it difficult to restart the wells from those fields.

Taking the above drawbacks of prior art systems into consideration, the invention provides a system for extracting subsea hydrocarbon fluid comprising at least three discrete subsea developments for hydrocarbon extraction and a hydrocarbon receiving facility linked by a pipeline network configured to permit :

- 5           (a)     diversion of fluid from at least one of the subsea developments selectively to one or more of the other developments; and
- (b)     conveyance of fluid from each of the subsea developments to the receiving facility.

10           With such a system, if a first subsea development is providing a surplus of one type of fluid (e.g. water) and a second subsea development requires more of that fluid to function effectively (e.g. for pressure boosting water injection) then water can be conveyed through the pipeline network from the first to the second subsea development. Alternatively, gas could be routed to a subsea development where gas compression is available so that the gas could

15           be conveyed more effectively. Avoiding the requirement to: (a) convey surplus fluids to the receiving host facility; and (b) convey required fluids from the host to the subsea development will reduce the maximum throughput that the pipelines to and from the host are designed to accommodate and may even mean that the requirement for one or more pipelines is obviated. Furthermore, when water is

20           used for well pressure boosting, the tariff paid to the host operator will be reduced or even eliminated.

Fluids can accordingly be distributed around the pipeline network when needed depending on demand, thereby realising production efficiency.

25           Preferably, the pipeline network is also configured to permit conveyance of fluid from at least one of the subsea developments to the receiving facility selectively via two alternative routes so that any work which needs to be carried out on the pipelines or other parts of the system can be performed with minimum interruption to the production process. Also, the pipeline network allows efficient use of pipeline capacities.

The system preferably includes a plurality of receiving facilities, the pipeline network being configured to permit conveyance of fluid from each of the developments to any of the receiving facilities. Each receiving facility may be in the form of an offshore oil rig which may be floating or seabed supported, an on-shore host facility or a floating storage and production unit. With such an arrangement, if one receiving facility only has the capability of catering for one type of fluid (e.g. liquid) and another receiving facility has the capability of catering for several fluid types (e.g. liquid and gas) then the flow of fluids through the pipeline network can be controlled to route the produced fluids to appropriate receiving facilities. Furthermore, if the maximum capacity of a particular receiving facility is reached or if a receiving facility becomes unavailable for use, possibly because of political factors or because of maintenance requirements, then it will be easily possible to divert produced fluids to an alternative receiving facility.

To increase the flexibility of the system, the pipeline network preferably includes, between at least two of the developments, plural pipelines suitable for respectively conveying different fluids such as hydrocarbon liquid, hydrocarbon gas and water.

The system preferably also includes a control means for controlling flows of fluids between the subsea developments and between the developments and the or each receiving facility.

The subsea developments and the one or more receiving facilities may also be connected by a network of power and/or control lines and/or chemical injection lines for conveying electric and/or hydraulic power and/or control signals and/or chemical injection fluids. These power and control lines and chemical injection lines conveniently follow the same routes as those followed by the pipes of the pipeline network but need not do so. With such an arrangement, the network could be used to distribute power and/or control signals to the subsea developments and also possibly to an offshore host facility via a choice of routes.

The control means may employ advanced computer protocols to standardise control hardware used to control the operation of the subsea developments and the flow of fluids therebetween through the pipeline network. Such a control means would preferably operate by automatically sensing what  
5 items of hardware were in use at a particular subsea development. Each item of hardware may include an electronic chip containing identification information.

The control system may enable control of production rates and flow distribution in the pipeline network from a remote location which, by the use of global satellite communications, could be anywhere in the world. Control could  
10 be effected from any suitable input/receiving device such as a personal computer, a personal digital assistant, a mobile telephone etc.

The control system may also include means to calculate the best place to store or dispose of a particular fluid thereby ensuring efficient use of the produced fluids.

15 By providing a control system which controls the distribution of fluids, power and control over a large seabed area and between the plurality of subsea developments, the need for host platforms serving groups of subsea developments will be at least reduced.

The control means may include signal processing means located at the  
20 subsea developments which communicate with each other and can control, at least to a limited extent, the distribution of fluids around the pipeline network, possibly independently of the host or receiving facility.

The control means preferably includes, at at least one of the subsea developments, a monitoring means for monitoring parameters pertaining to that  
25 subsea development.

Preferably at least one of the subsea developments includes separating means for at least substantially separating constituent components of fluid received by the development from each other.

In order to increase the flexibility of the system and permit each subsea  
30 development to be adapted as the requirement on it changes, at least one and

preferably each of the subsea developments comprises a manifold to which pipelines of the network are connected and at least one retrievable module including equipment for acting on fluid received thereby and docked with the manifold for fluid connection to the pipeline network. Such equipment is  
5 designed by Alpha Thames Ltd of Essex, United Kingdom, and marketed under the name AlphaPRIME. With such an arrangement, as the requirement of a particular subsea development changes, a module in the development can be replaced by an alternative one with different processing capabilities.

According to a second aspect of the invention, there is provided a method  
10 of operating a system for extracting subsea hydrocarbon fluid, the system comprising plural discrete subsea developments for hydrocarbon extraction and a hydrocarbon receiving facility linked by a pipeline network and control means for controlling flows of fluids between the subsea developments and between the subsea developments and the receiving facility, the control means including  
15 monitoring means for monitoring parameters pertaining to the subsea developments, the method comprising the steps of:

- (i) monitoring parameters at a first subsea development and identifying a requirement for a first fluid type;
- (ii) monitoring parameters at a second subsea development and  
20 identifying a surplus of the first fluid type; and
- (iii) operating the control means to convey a quantity of the first fluid from the second to the first subsea development via the pipeline network.

Preferably the system includes plural receiving facilities and at least one of the subsea developments includes separating means for at least substantially  
25 separating constituent components of fluid received by the development from each other; the method including the steps of :

- (i) at least substantially separating fluid received by the subsea developments into first and second fluid types;
- (ii) conveying the first fluid type to one of the receiving facilities; and

(iii) conveying the second fluid type to another of the receiving facilities.

The invention will now be described by way of example only with reference to the accompanying schematic drawings in which:

5        FIG. 1 shows a system according to the invention for extracting hydrocarbons from plural subsea developments; and

FIG. 2 shows a typical module for use in one of the subsea developments shown in Fig. 1.

10        The system 1 shown in Fig. 1 includes four receiving facilities, two of which 2, 4 are shore-based, one of which comprises an offshore fixed platform 6 and one of which comprises a floating production and storage unit 8. The system also includes five subsea developments 10, 12, 14, 16 and 18. Each of the subsea developments comprises a base structure 20 containing one or more piping manifolds to which one or more retrievable modules 22 are connected.

15        The system shown in Fig. 1 includes base structures 20 all configured to accept two modules. Each base structure could alternatively be configured to accept any other number of modules. Plural wellheads 32 supply production fluid to the manifolds in the associated base 20 by means of production fluid conduits 34.

20        A typical retrievable module 22 is shown in Fig. 2 which is designed to effect separation of two fluids (e.g. liquid such as oil and gas) from each other. Each module could however be configured in an alternative manner depending on requirements. The modules could for example be configured to separate three fluids from each other by means of three phase separators or simply route fluid round a loop and into an output pipe of the manifold in the base structure.

25        The module 22 includes a module part 24 of a multi-ported fluid connector 27 which is adapted to mate with a complementary base part 26 thereof forming part of the base 20. Each connector part 24, 26 includes isolation valves 28, 30 for isolating flow to and from the module 22 when it is to be replaced. Production fluid from the production fluid conduits 34 is routed to  
30        the module by fluid inlet pipes 36 in the base 20 via the multi-ported fluid



connector 27 and into inlet conduits 38. The flow through the inlet conduits 38 is regulated by pressure control valves 40 which are adjusted by actuators 42 under the control of a control module 44. Electrical signal lines are shown with dashed lines and fluid conduits and pipes are shown with solid lines in Fig. 2.

5 The control module 44 receives power from a power line 46 via a disengageable power connector 48 and a transformer 49, and signals from a signal line 50 via a disengageable signal connector 52. Pressure transducers 54 monitor pressure in the inlet conduit 38 and if over-pressurisation is detected, actuators 56 of two series connected fail-safe closed valves 58 are de-powered  
10 to allow the valves 58 to close. Fluid from the inlet conduit 38 is routed into a separation vessel 60 where hydrocarbon gas 62 is separated from produced liquid 64. The separator may be a gravity separator as shown or a dynamic separator such as a hydro-cyclone separator. Gas is routed out of the vessel 60 and through a gas outlet conduit 66, a gas compressor 68 and a venturi meter  
15 70. Produced liquid 64 is routed via a liquid outlet conduit 72, a liquid pump 74 and a flow control valve 76 controlled by an actuator 78 to the multi-ported fluid connector 27. The interface between the gas 62 and produced liquid 64 is detected by a level sensor 80, the output from which is used to control the flow control valve 76. Partial closing of the flow control valve 76 forces produced  
20 liquid to be returned to the separator vessel 60 via a flow restrictor 82 and a liquid recirculation pipe 84. This would be effected if the interface between the gas and the produced liquid in the vessel 60 became too low. Injection chemicals are routed to the module via chemical injection connectors 86 and chemical injection lines 88 from which chemicals can be injected into the gas  
25 and liquid outlet conduits 66, 72. Gas and liquid are respectively led away from the module 22 by a gas outlet pipe 90 and a liquid outlet pipe 92 constituting part of the manifold system in the base structure 20.

The pipework manifold in each base structure 20 is connected by a pipeline network to the pipework manifold of at least two other subsea  
30 developments and in certain cases one of the receiving facilities 2, 4, 6 or 8.

The pipeline network is shown schematically in Fig. 1 by solid lines extending between the subsea developments and the receiving facilities. Although only one line is shown extending between the subsea developments/receiving facilities or nodes of the network, each internodal pipeline connection 94 may include plural pipelines. Separate pipelines may be provided for oil, gas, water, injection chemicals and/or test flows for example. A network of internodal signal or power and control lines 96 also extends between the subsea developments and the receiving facilities which signal lines are shown by broken lines. The signal line network is shown to have the same internodal connections as the pipeline network. These two networks may not necessarily be coincident however and some of the signal lines may for example be replaced by communication links via some remote receiving and transmitting means, eg a satellite communication system.

When the system 1 shown in Fig. 1 is operating, continuous or periodic communication between individual subsea developments and between the subsea developments and one or more of the receiving facilities will take place by means of a data bus constituted by the signal line network. The control module 44 of each retrievable module 22 will be configured to transmit information via the data bus concerning the operation of each retrievable module 22 including information such as the quantity of one or more fluids being received and/or separated by the module, the pressure sensed by some or all of the pressure sensors 54 etc. The control module 44 will also be adapted to receive such information from other subsea developments via the data bus. Some or all of this information will also be transmitted to the receiving facilities 2, 4, 6 and 8. The data bus is also configured to transmit control signals from the receiving or host facilities to the subsea developments.

Valves (not shown) arranged to control the flows of fluids between the subsea developments and between the subsea developments and the receiving facilities will be controlled to route fluids in an appropriate manner through the network of internodal pipelines 94. The control of the valves may be effected

directly as a result of communication between two or more subsea developments or may involve communication with one of the host facilities or even some remote control means possibly via satellite or other like communication systems. The subsea developments or nodes can accordingly  
5 act as separation, diverter or boosting stations depending on demand. Furthermore, power and control signals and subsea development supporting fluids such as injection water and chemicals have alternative routes from a selected host to a particular subsea development.

An ideal medium for incorporation into the network system described  
10 above would be one using advanced computer protocols enabling computer control hardware to be standardised. By using multi-layered hardware and software architecture, changes to the system (e.g. changing one type of removable module for another having a different function) could be readily catered for. Control software and hardware could be arranged to automatically  
15 recognise that the change had occurred and communicate with the control module of the new removable module appropriately. To avoid the requirement of changing control system hardware, it is capable of being remotely upgraded by software methods to take account of the installation of the new module or other apparatus.

CLAIMS:

1. A system (1) for extracting subsea hydrocarbon fluid comprising at least three discrete subsea developments (10,12,14,16,18) for hydrocarbon extraction  
5 and a hydrocarbon receiving facility (2,4,6,8) linked by a pipeline network (94) configured to permit :
  - (a) diversion of fluid from at least one of the subsea developments selectively to one or more of the other developments; and
  - (b) conveyance of fluid from each of the subsea developments  
10 (10,12,14,16,18) to the receiving facility (2,4,6,8).
2. The system as claimed in claim 1, wherein the pipeline network (94) is also configured to permit conveyance of fluid from at least one of the subsea developments (10,12,14,16,18) to the receiving facility (2,4,6,8) selectively via at  
15 least two alternative routes.
3. The system as claimed in claim 1 or 2, including a plurality of receiving facilities (2,4,6,8), the pipeline network (94) being configured to permit conveyance of fluid from each of the subsea developments (10,12,14,16,18) to  
20 any of the receiving facilities (2,4,6,8).
4. The system as claimed in claim 1, 2 or 3, wherein the pipeline network (94) includes, between at least two of the subsea developments (10,12,14,16,18), plural pipelines suitable for respectively conveying different  
25 fluids such as hydrocarbon liquid, hydrocarbon gas and water.
5. The system as claimed in any preceding claim, including a control means (44) for controlling flows of fluids between the subsea developments (10,12,14,16,18) and between the subsea developments (10,12,14,16,18) and  
30 the or each receiving facility (2,4,6,8).

6. The system as claimed in claim 5, wherein the control means (44) includes, at at least one of the subsea developments (10,12,14,16,18), a monitoring means (54,68,70,80) for monitoring parameters pertaining to that  
5 subsea development.

7. The system as claimed in claim 5 or 6, wherein the control means (44) include signal processing means located at the subsea developments (10,12,14,16,18) which communicate with each other and can control, at least to  
10 a limited extent, the distribution of fluids around the pipeline network (94).

8. The system as claimed in claim 5, 6 or 7, wherein the control means (44) is arranged to operate by automatically sensing what items of hardware are in use at a particular subsea development (10,12,14,16,18).  
15

9. The system as claimed in claim 8, wherein each item of hardware includes an electronic chip containing identification information.

10. The system as claimed in any one of claims 5 to 9, including a remote  
20 input/receiving device for effecting control of the flow of said fluids.

11. The system as claimed in any one of claims 5 to 10, wherein the control means (44) also include means to calculate the best place to store or dispose of a particular fluid.  
25

12. The system as claimed in any preceding claim, wherein at least one of the subsea developments (10,12,14,16,18) includes separating means (60) for at least substantially separating constituent components of fluid received by the subsea development from each other.  
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(iii) operating the control means (44) to convey a quantity of the first fluid from the second to the first subsea development via the pipeline network (94).

- 5 18. The method as claimed in claim 17, wherein the system includes plural receiving facilities (2,4,6,8) and at least one of the subsea developments (10,12,14,16,18) includes separating means (60) for at least substantially separating constituent components of fluid received by the development (10,12,14,16,18) from each other, the method including the steps of:
- 10 (i) at least substantially separating fluid received by the subsea developments (10,12,14,16,18) into first and second fluid types;
- (ii) conveying the first fluid type to one of the receiving facilities (2,4,6,8); and
- (iii) conveying the second fluid type to another of the receiving
- 15 facilities.

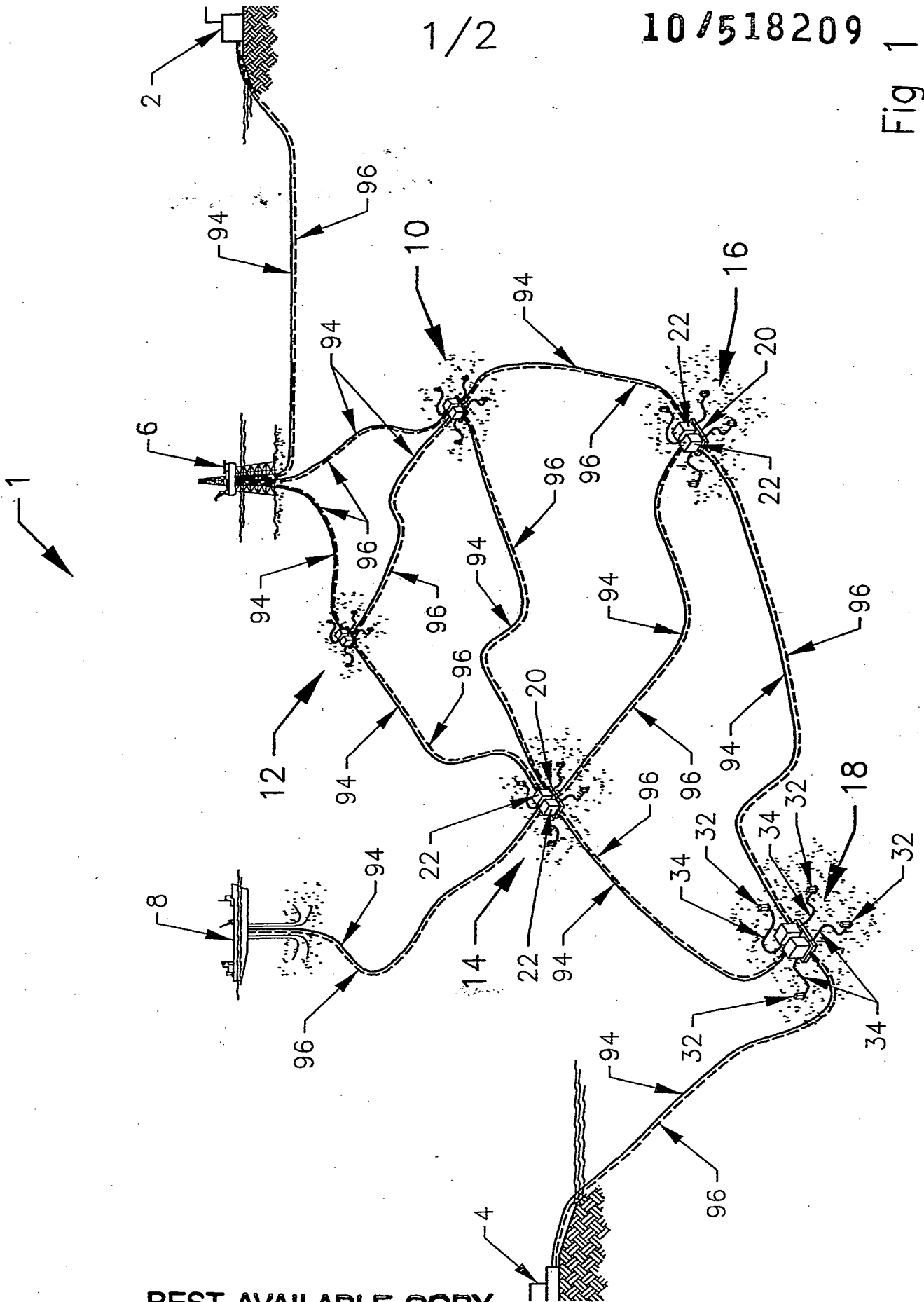
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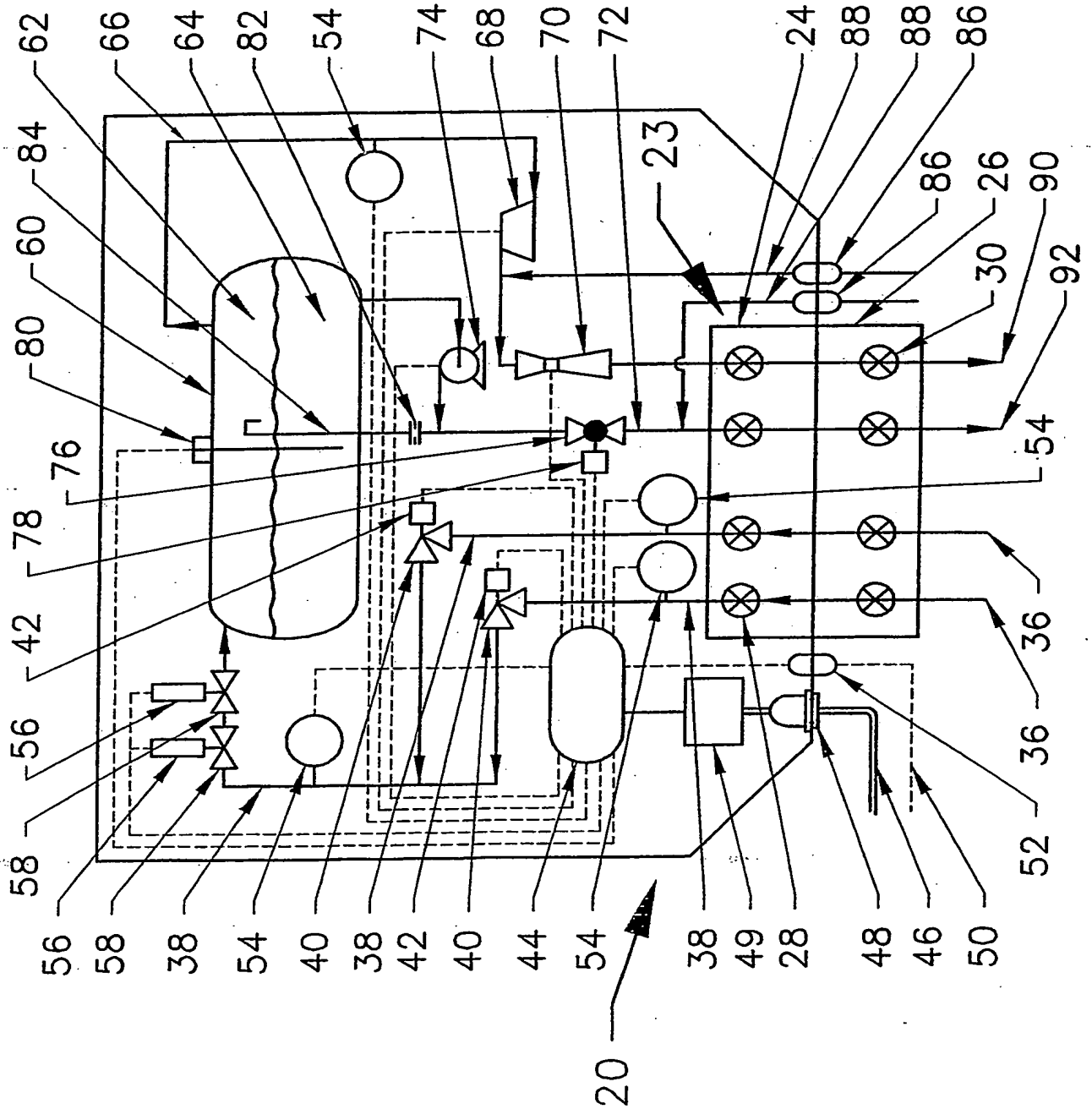
Fig 1



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## INTERNATIONAL SEARCH REPORT

Internat Application No

CT/GB 03/02767

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 E21B43/017

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According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 E21B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 4 052 703 A (COLLINS SR JERRY ALAN ET AL) 4 October 1977 (1977-10-04) column 5, line 15 - line 31	1,2,5-7, 10,13-15
Y	column 6, line 53 - line 55; figure 1	3,4,11, 12
Y	GB 2 299 108 A (NORSKE STATS OLJESELSKAP) 25 September 1996 (1996-09-25) abstract; figure 1	3,11
Y	US 5 154 741 A (DA COSTA FILHO FERNANDO H) 13 October 1992 (1992-10-13) abstract; figure 1	4,12
A	GB 2 028 400 A (OTIS ENG CORP) 5 March 1980 (1980-03-05) figure 2	

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☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

## \* Special categories of cited documents:

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
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- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*G\* document member of the same patent family

Date of the actual completion of the international search

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Name and mailing address of the ISA

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## INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US 03/02767

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P, X	US 2002/195251 A1 (UNDERDOWN DAVID R ET AL) 26 December 2002 (2002-12-26) figure 12 -----	1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

Application No  
PCT/GB 03/02767

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